BOUNDARY LAYER FLOW AND HEAT TRANSFER FOR MAXWELL FLUID AND VISCOELASTIC NANOFLUID OVER A STRETCHING SHEET

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SUPERVISOR’S DECLARATION

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science (Mathematics).

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Permasalahan aliran lapisan sempadan banyak diaplikasikan dalam industri dan kejuruteraan. Aplikasi ini adalah pelakaran filem plastik, penghasilan gentian kaca, penggelekan panas dan pelbagai proses dalam industri pembuatan. Ciri-ciri produk akhir bergantung kepada cecair pendingin yang digunakan dan kadar regangan. Bendalir tak-Newtonan boleh dibahagikan kepada beberapa kategori seperti viscoelastik, kelikatan kebergantungan-masa dan kelikatan tak-Newtonan. Contoh bendalir ini adalah seperti minyak, sos, pes makanan, cat dan larutan koloid. Kajian bendalir tak-Newtonan mendapat lebih perhatian kerana prestasinya yang baik di dalam industri dan penggunaan teknologi jika dibandingkan dengan bendalir Newtonan. Dalam tesis ini, terdapat dua jenis bendalir tak-Newtonan yang dicadang dan diperiksa iaitu cecair Maxwell dan nanobendalir visco elastik. Terdapat dua jenis syarat sempadan yang telah dikaji dalam tesis ini iaitu syarat sempadan yang ditetapkan suhu dinding dan keadaan gelinciran. Model yang dicadangkan untuk setiap permasalahan bergantung kepada sistem persamaan menakluk yang selari dengan syarat awal dan syarat sempadan. Pembolehubah tak berdimensi yang sesuai diperkenalkan dan diperturunkan kepada bentuk persamaan menakluk tak berdimensi. Penyelesaian berangka bagi persamaan pembezaan biasa diselesaikan dengan menggunakan kaedah Luruan. Seterusnya, kaedah Luruan dijalankan untuk menyelesaikan hasil persamaan-persamaan pembezaan biasa menggunakan atur cara sedia ada dalam perisian MAPLE-13. Penyelesaian ini perlu asimptot dan memuaskan syarat awal dan syarat sempadan. Pengiraan berangka dilakukan untuk pelbagai nilai parameter tak berdimensi seperti nombor Prandtl Pr, parameter regangan ε, parameter sedutan S, parameter magnetik M, parameter Maxwell β, parameter Brown N_b, parameter thermopil N_t, parameter sinaran terma N_R, nombor Lewis Le, parameter gelinciran halaju dan terma dipertimbangkan. Perbandingan keputusan sekarang dengan hasil yang telah diterbitkan terdahulu telah dilakukan dan didapati sangat memuaskan. Keputusan berangka yang dipersembahkan dalam kajian ini adalah profil suhu, profil halaju, pekali geseran kulit, pekali pemindahan haba, nombor Nusselt dan nombor Sherwood. Peringkatan parameter regangan dan ciri-ciri terma menghasilkan penurunan pada suhu dinding dan ketebalan terma lapisan sempadan. Selain itu, peningkatan pada parameter Maxwell dan sedutan membawa kepada peningkatan pemindahan haba setempat manakala penurunan terhadap pekali geseran kulit, suhu dan halaju profil. Kehadiran parameter gelinciran halaju telah mempercepatkan pergerakan zarah-zarah bendalir dari keadaan pegun kepada halaju tertentu di permukaan. Keadaan ini telah mengurangkan pekali geseran kulit dan juga kesan parameter regangan.

ABSTRACT

The problem of boundary layer flow has many applications in industry and engineering field. Some of these applications are drawing of plastic films, glass fiber production, hot rolling and many others in industrial manufacturing processes. The final product requested characteristics depends on the cooling liquid used and the rate of stretching. Non-Newtonian fluids can be defined in several categories like viscoelastic, time-dependent viscosity and non-Newtonian viscosity. Such fluids like oils, ketchup, food paste, paints and colloidal solutions. The study of non-Newtonian fluids has gain great attraction due to their better performance in industrial and technological applications if compared to Newtonian fluids. In this thesis, there are two types of non-Newtonian fluids namely Maxwell fluids and viscoelastic nanofluids has been examined and proposed. There are two types of boundary conditions that will be studied in this thesis, that are prescribed wall temperature (PWT) and slip condition. The proposed model for each problem depends on the system of governing equations which along with imposed initial and boundary conditions. Suitable non-dimensional variables are then introduced and reduce the governing equations into dimensionless form. The numerical solutions of ordinary differential equations are solved by shooting method. Then, shooting method is carried out to solve the resulting system of ordinary differential equations through "build in" program in MAPLE-13 software. These solutions satisfy and asymptotic for the applied of imposed initial and boundary conditions. Numerical computations are carried out for various values of the parameters of the problems, which include the Prandtl number $\Pr$, stretching parameters ε, suction parameters S, magnetic parameter M, Maxwell parameters β, Brownian parameter N_b, thermophoresis parameter N_t, thermal radiation parameters N_R, Lewis number Le, velocity and thermal slip parameter are considered. Comparisons of present result with previously published results are done and it is found to be in a good agreement. Numerical results presented in this study are the temperature profile, the velocity profile, the skin friction coefficient, the local heat transfer coefficient, the Nusselt number and the Sherwood number. The rises of stretching parameter and thermal characteristics are resulting on decreasing in the wall temperature and thermal boundary layer thickness. Other than that, the increasing in the Maxwell and suction parameter leads to increase on the local heat transfer while the skin friction coefficient, velocity and temperature profile become decrease. The presence of velocity slip parameter has accelerated the movement of fluid particle at surface from static to a certain velocity. This situation reduces the skin friction coefficient as well as the effect on stretching parameters.

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LIST OF SYMBOLS

a, b	Positive constant for stretching rate
β_0	Induced magnetic field
C	Volume fraction
C_f	Local skin friction coefficient
C_p	Specific heat capacity
C_w	Concentration near the plate
C_∞	Concentration far away from the plate
D	Mass diffusivity
D_B	Brownian diffusion coefficient
D_T	Thermophoresis diffusion coefficient
h_s	Heat transfer coefficient
j_w	Surface mass flux
K	Dimensionless viscoelastic parameter
K_f	Flow consistency parameter
k	Thermal conductivity
k_0	Viscoelastic parameter
k^*	Mean absorption coefficient
Le	Lewis number
M	Magnetic parameter
N_b	Brownian parameter
N_t	Thermophoresis parameter
N_R	Thermal radiation parameter
Nu_x	Local Nusselt number
$\Pr$	Prandtl number
q_r	Radiative heat flux
q_w	Surface heat flux
Re_x	Local Reynolds number

S	Suction parameter
Sh_x	Local Sherwood number
T	Temperature
T_w	Wall temperature
T_∞	Ambient temperature
u, v	Velocity components along x and y axes
$u_w(x)$	Stretching sheet velocity
$u_e(x)$	External velocity

Greek symbols

α_m	Nanofluid thermal diffusivity
β	Maxwell parameter
ε	Stretching parameter
δ	Thermal slip parameter
δ^*	Dimensional thermal slip parameter
γ	Velocity slip parameter
γ^*	Dimensional velocity slip parameter
ρ	Density of nanofluid
ρ^*	Fluid normal stress
σ	Electricity conductivity
σ^*	Stefan Boltzmann constant
ν	Kinematic viscosity
λ	Relaxation time parameter
ψ	Stream function

μ	Dynamic viscosity
τ_w	Shear stress surface
θ	Dimensionless temperature
ϕ	Dimensionless concentration
f	Dimensionless stream function
$\left(\rho c_p\right)_f$	Effective heat capacity of nanoparticle

Subscipts

w	Condition at wall
∞	Condition at infinity

LIST OF ABBREVIATIONS

IVP	Initial Value Problem
MHD	Magnetohydrodynamic
PWT	Prescribed Wall Temperature
RKF	Runge-Kutta Fehlberg

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